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Species Persistence or Extinction: Through a Mathematical Lens

ScienceDaily (Nov. 12, 2012) — Scientists have estimated that there are 1.7 million species of animals, plants and algae on earth, and new species continue to be discovered. Unfortunately, as new species are found, many are also disappearing, contributing to a net decrease in biodiversity. The more diversity there is in a population, the longer the ecosystem can sustain itself. Hence, biodiversity is key to ecosystem resilience.

Disease, destruction of habitats, pollution, chemical and pesticide use, increased UV-B radiation, and even the presence of new species are some of the causes for disappearing species. "Allee effect," the phenomenon by which a population's growth declines at low densities, is another key reason for perishing populations, and is an overriding feature of a paper published last month in the *SIAM Journal on Applied Mathematics*.

Authors Avner Friedman and Abdul-Aziz Yakubu use mathematical modeling to analyze the impact of disease, animal migrations and Allee effects in maintaining biodiversity. Some Allee effect causes in smaller and less dense populations are challenges faced in finding mating partners, genetic inbreeding, and cooperative behaviors such as group feeding and defense. The Allee threshold in such a population is the population below which it is likely to go extinct, and above which persistence is possible. Declining populations that are known to exhibit Allee effects currently include the African wild dog and the Florida panther.

Author Abdul-Aziz Yakubu explains how disease can alter the behavior of populations that exhibit Allee effects. In infectious disease studies, the reproduction number or Ro is defined as the expected number of secondary infections arising from an initial infected individual during the latter's infectious period. For regular populations, the disease disappears in the population if (and only if) the Ro is less than 1. "In the present paper, we deal with a population whose survival is precarious even when Ro is less than 1," says Yakubu. "That is, independent of Ro, if the population size decreases below a certain level (the Allee index), then the individuals die faster than they reproduce."

A previous study by the authors showed that even a healthy stable population that is subject to Allee effects would succumb to a small number of infected individuals within a single location or "patch," causing the entire population to become extinct, since small perturbations can reduce population size or density to a level below or close to the Allee threshold.

Transmission of infectious diseases through a population is affected by local population dynamics as well as migration. Thus, when trying to understand the resilience of the ecosystem, the global survival of the species needs to be taken into account, that is, how does movement of animals between different locations affect survival when a disease affects one or more locations? Various infectious disease outbreaks, such as the West

Nile virus, Phocine and distemper viruses have been seen to spread rapidly due to migrations.

In this study, the authors extend their previous research by using a multi-patch model to analyze Allee effects within the context of migration between patches. "We investigate the combined effect of a fatal disease, Allee effect and migration on different groups of the same species," Yakubu says. In their conclusions, the host population is seen to become extinct whenever the initial host population density on each patch is lower than the smallest Allee threshold. When the initial host population has a high Allee threshold, the population persists on each patch if the disease transmission rates are small and the growth rate is large. Even in the case of high Allee thresholds, the host population goes extinct if the disease transmission rate is high, and growth rate and disease threshold are small. The presence of a strong Allee effect adds the possibility of population extinction even as the disease disappears.

The research can be applied to various kinds of populations for conservation studies. "Our models and results are very general and may be applied to several declining populations," says Yakubu. "For example, the African wild dog, an endangered species, is vulnerable to fatal diseases like rabies, distemper and anthrax. Our models can be used to investigate how the Allee threshold of one subpopulation of an African wild dog pack at a geographical location is influenced by the collective migrations of several wild dog populations from different packs with different Allee thresholds."

The authors' mathematical models and rigorous analysis can be extended with the help of field data. "Future work will need to get specific field data in order to refine the model and use it to design conservation strategies for preservation of these somewhat endangered and declining populations,"says Yakubu.

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1. Avner Friedman, Abdul-Aziz Yakubu. **Host Demographic Allee Effect, Fatal Disease, and Migration: Persistence or Extinction**. *SIAM Journal on Applied Mathematics*, 2012; 72 (5): 1644 DOI: 10.1137/120861382

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